The development of *Squilla*, by Dr. W. K. Brooks,[1] concludes our notice of the literature of American Crustacea for 1879. While the successive stages in the development of *Palæmonetes* were in most cases the result of the moulting of the larvæ in confinement, Dr. Brooks had to depend more upon the results of surface skimming for his younger stages, and hence his paper, though of great value, lacks the completeness of the last noticed one of Dr. Faxon. The first stage observed was that which formed the genus *Alima* of the earlier systematists; the eyes, both pairs of antennæ, mandibles, maxillæ and first two pairs of maxillipeds being present, the second pair possessing something of the raptorial character found in the adult. The eighth to tenth segments (9–11 Brooks) are differentiated, the eleventh to thirteenth (12–14 Brooks) are still united and all are without appendages. The abdomen consists of six joints, of which four bear appendages; the carapax with its long spines resembles somewhat that of the Decapod zoea. In the next stage the thoracic segments are all free. The third stage observed represents the changes of at least two moults, the remaining thoracic and fifth abdominal appendages being represented by small buds. The next form figured has the carapax and telson somewhat like those of the adult, while the appendages are all present, those of the abdomen, judging by the figures, having assumed something of their adult branchial character.

I would here return thanks to the various authors mentioned for copies of their papers.

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THE STRUCTURE OF THE EYE OF TRILOBITES.

BY A. S. PACKARD, JR.

BEYOND the fact that the entire eye of certain Trilobites, and enlarged views of the outer surface of the cornea of the eye, have been described and figured in Burmeister's work on the organization of Trilobites and in various palæontological treatises in Europe and North America, especially by Barrande in his great work on Trilobites, I am not aware that any one has given a description of the internal structure of the hard parts of the eye of Trilobites.

[1] Larval stages of *Squilla empusa*. Chesapeake Zoölogical Laboratory. Scientific Results of the Session of 1878, pp. 143–170, pls. 9–13 (1879).

The full bibliography of treatises relating to these animals in Bronn's Die Classen und Ordnungen des Thierreichs, carried up to 1879 by Gerstacker, contains references to no special paper on this subject, and the résumé by Gerstacker of what is known of the structure of the eye, only refers to the external anatomy of the cornea, the form of the facets and their number in different forms of Trilobites. He shows that observers divide them into simple and compound; the former (ocelli) are found in the genus *Harpes*. These "ocelli" are said to be situated near one another, and are so large that the group formed by them can be seen with the unaided eye; the surface of the single "ocellus" appears, under the glass, smooth and shining. From the description and the figure of the eye enlarged, from Barrande, it would seem as if each eye was composed of three large simple ones; so that these eyes are really aggregate, and not comparable with the simple eye or ocellus of Limulus and the fossil Merostomata.[1] Moreover the situation of these so-called ocelli is the same as that of the compound eyes of other Trilobites.

The Trilobites with compound eyes are divided into two numerically very dissimilar groups; the first comprising Phacops and Dalmanites alone, and the second embracing all the remaining Trilobites, excepting of course the eyeless genera, Agnostus, Dindymene, Ampyx and Dionide. The eyes of Phacops and Dalmanites are said by Quendstedt and Barrande not to be *compound* eyes in the truest sense, but *aggregated* eyes (*Oculi congregati*). But judging by Barrande's figures of the eyes of *Phacops fecundus* and *P. modestus* (Barrande, Vol. 1, Suppl. Pl. 13, Figs. 12 and 22), and our observations on the exterior of the eye of an undetermined species of *Phacops*, kindly sent us by Mr. J. F. Whiteaves, Palæontologist of the Canadian Geological Survey, we do not see any essential difference between the form and arrangement of the corneal lenses of Phacops and Asaphus, and are disposed to believe that the distinctions pointed out by the above named authors are artificial.

For my material I am mainly indebted to Mr. C. D. Walcott, who has so satisfactorily demonstrated the presence in Trilobites of jointed cephalo-thoracic appendages. On applying to him for specimens, and informing him that I wished to have sections

[1] The eyes of the fossil Merostomata (Eurypterus and Pterygotus) are evidently in external form and position, judging by Mr. Woodward's figure, exactly homologous with the ocelli and compound eyes of Limulus.

made of the eyes of Trilobites to compare with those of Limulus, he very generously sent me his own collection of sections of the eyes of *Asaphus gigas* and *Bathyurus longistrinosus*, which he had prepared for his own study, also other eyes, and especially the shell or carapace of a large Asaphus, from Trenton Falls, showing the eye and the projecting points of the corneal lenses. Prof. Samuel Calvin kindly sent me the eyes of an unknown Trilobite from the Trenton limestone, one specimen showing the pits made in the mud by the projecting ends of the corneal lenses, while to Mr. Whiteaves I am indebted for a well preserved eye of Phacops. To Dr. C. A. White, Palæontologist of the U. S. Geological Survey, I am also indebted for eyes of Calymene.

First turning our attention to the casts and natural sections; that of the interior of the carapace, including the molted cornea of *Asaphus gigas*, is noteworthy. When the concave or interior

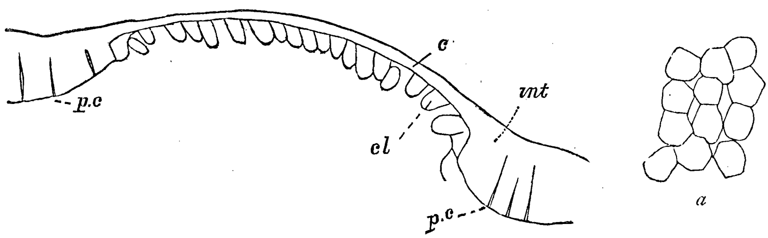

FIG. 1.—Section of hard parts of eye of Limulus; *c*, cornea; *int*, integument: *pc*, pore canals; *cl*, corneal lens. × 30 diams. FIG. 1*a*, optical section of facets.

surface of this specimen is placed under a magnifying power of fifty diameters, the entire surface is seen to be rough with the ends of the minute solid conical corneal lenses which project into the body-cavity. This is exactly comparable with the cast shell of Limulus and its solid corneal lenses projecting into the body cavity (Fig. 1). Those of Asaphus only differ in being much smaller and more numerous, and perhaps rather more blunt. Without much doubt the ends of the corneal lenses of Asaphus, as in Limulus, were enveloped in the retina, the animal molting its carapace, the hypodermis with the retina being retained by the trilobite, while the corneal lenses were cast with the shell.

In the specimen of the unknown trilobite from Iowa, received from Prof. Calvin, the corneal lenses, seen externally, are quite far apart, arranged in quincunx order; the lenses are round and decidedly convex on the external surface. In a natural section, where the

eye has been broken into two, the conical lenses are seen to extend through the cornea as cup-shaped or conical bodies, and are quite distinct from the cornea itself. In another broken eye of the same species, the cornea is partly preserved, and two of the corneal lenses are seen to extend down into and partially fill two hollows or pits; these pits are evidently the impressions made in the fine sediment which filled the interior of the molted eye or cornea!

Thus in the *Asaphus gigas* noticed above, we have the entire inside of the cornea with the cone-like lenses projecting from the concave interior; while in the last example we have the impressions made by the cones in the Silurian mud which silted into the cornea after the trilobite had cast its shell.

Farther evidence that the trilobite's eye was constructed on the same pattern as that of the living horse-shoe crab is seen in the sections made by Mr. Walcott. We will first describe, briefly, the eye of Limulus. Fig. 1 represents a section through the cornea of Limulus; *c*, the cornea, which is seen to be a thinned portion of the integument; *pc*, indicates one of the nutrient or pore canals, which are filled with connective tissue extending into the integument from the body cavity; *cl*, is one of the series of solid conical corneal lenses. These are buried partly in the black retina, and the long slender optic nerve just before reaching the eye subdivides, sending a branch to each facet or cornea, impinging on the lens. Fig. 1*a* represents a vertical view of the corneal lenses or facets, magnified fifty diameters, as seen through the transparent cornea. It will be seen that they are slightly hexagonal and arranged in quincunx order; their external surface is flat, though that of the ocelli is slightly convex.

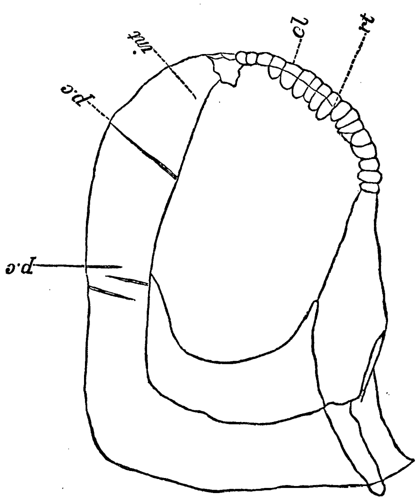

Fig. 2.—Section through the eye of a trilobite; lettering as in Fig. 1. × 50 diams.

Now if we compare with the horse-shoe crab's eye that of the

trilobite (*Asaphus gigas*, Fig. 2), we see that the eye is raised upon a tubercle-like elevation of the carapace; the integument (*int*) is about as thick as that of Limulus, and it contains similar pore-canals (*pc*); the eye itself, or cornea, occupies a rather small area; its exterior surface, instead of being smooth as in Limulus, is tuberculated, or divided up into minute convex areas; these convexities are the external surfaces of the corneal lenses, which extend through the cornea, so that its surface is rough instead of smooth as in Limulus; *cl* indicates one of the corneal lenses which are arranged side by side; they are of slightly different lengths and thicknesses, and the rather blunt free ends project into the cavity of the eye, which in the fossil is filled with a translucent calcite.

It is quite apparent that we have here the closest possible homology between the hard parts of the eye of Limulus and the Asaphus. Another point of very considerable interest is a tolerably distinct dark line (*rt*) which seems to run across from one lens to another, and which may possibly represent the external limits of the retina or pigment mass in which the ends of the lenses were probably immersed; should this be found to be the indications of the outer edge of the retina, it would be a most interesting fact in favor of our view of the identity between the eyes of the two types of *Palæocarida* under consideration.

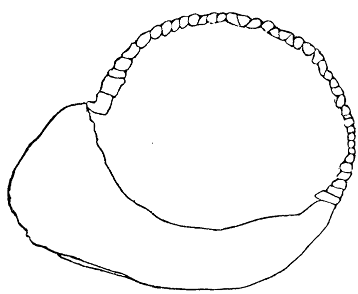

FIG. 3.—Cornea of Asaphus.

Another section sent us by Mr. Walcott is represented by Fig. 3; it is from *Asaphus gigas*, but represents a less elevated and broader part of the eye than that seen in Fig. 3; the section does not so well exhibit the free ends of the corneal lenses. Fig. 3 *a* represents a transverse view of the eye of *Asaphus gigas*, showing the hexagonal form of the facets, and their quincunx arrangement.

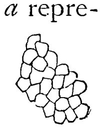

FIG. 3*a*.

This hexagonal appearance of the corneal lenses is still retained in natural vertical sections of eyes of the same genus; where with a good Tolles lens the sides of the cones are seen to be angular. Fig. 4 represents a few such cones. I do not understand to what this hexagonal appearance is due; for both in

Limulus and the Trilobites the corneal lenses appear usually to be round, and yet in making a camera drawing (as are all those here represented) of the cornea of Limulus from above, they present the same hexagonal appearance as in the Trilobites. The cause of this I leave to others to explain.

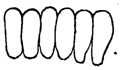

FIG. 4. — Lenses of Asaphus.

In a section (transverse) of the cornea of *Bathyurus longistrinosus*, received from Mr. Walcott, the lenses are seen to be very irregular, five or six-sided, and very irregularly grouped, not arranged in distinct rows.

From the facts here presented it would seem evident that the hard parts of the eye of the Trilobites and of Limulus are, throughout, identical. The nature of the soft parts will, as a matter of course, always remain problematical; unless the dark line indicated in Fig. 3 *(cl)* really represents the outer edge of the pigment of the retina; but however this may be, judging by the identity in structure of the solid parts, we have, reasoning by analogy, good evidence that most probably the eye of the Trilobites had a retinal mass like that of Limulus, and that the numerous small branches of the long slender optic nerve (for such it must have been) impinged on the ends of the corneal lenses. It has been shown by Grenacher and myself that the eye of Limulus is constructed on a totally different plan from that of other Arthropods; I now feel authorized in claiming that the trilobite's eye was organized on the same plan as that of Limulus; and thus when we add the close resemblance in the larval forms, in the general anatomy of the body-segments, and the fact demonstrated by Mr. Walcott that the Trilobites had jointed round limbs (and probably membranous ones), we are led to believe that the two groups of Merostomata and Trilobites are subdivisions or orders of one and the same sub-class of Crustacea, for which we have previously proposed the term *Palæocarida*.

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RECENT LITERATURE.

THE GEOLOGY OF WISCONSIN.[1]—This bulky report has not only a handsome typographical appearance, but is well illustrated by numerous excellent plates, and an atlas of maps. It bears every appearance of care and labor in its preparation, and of containing

[1] *Geology of Wisconsin, Survey of* 1873–1879. Vol. III, Accompanied by an Atlas of Maps. J. C. Chamberlain, Chief Geologist. Madison, Wis., 8vo. pp. 763.